Quantifying the impact of acidity on positronium formation and annihilation in zeolitic materials

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Positron annihilation lifetime spectroscopy (PALS) demonstrates unique sensitivity towards elucidating the connectivity of pore networks in zeolitic materials, which is based on the diffusional behavior of metastable *ortho*-positronium (*o*-Ps) species formed *in situ* upon positron implantation.[1] Chemical interactions between *o*-Ps and acid sites in a solid have been widely postulated to perturb the purely kinetic response.[2] However, the specific impact of the nature and amount of acid sites on the lifetime and intensity of different *o*-Ps components, and the implications for porosity analysis, have not been quantified. By studying a series of ZSM-5 (MFI structure) samples with tailored crystal size and Si:Al ratio, we map the dependence of the amount (Ps_{total}) and fractional distribution (Ps_{micro}, Ps_{vac}) of *o*-Ps measured on the concentration of Brønsted acid sites and the implantation depth of positions (**Figure 1**). By modeling the possible mechanisms of interaction, we show that the presence of Brønsted acid centers most significantly affects the thermalization and delocalization of *o*-Ps, while the impact on diffusion and correspondingly on Ps_{micro} and Ps_{vac} is negligible. The study of commercial ZSM-5 samples confirms the generality of the findings and permits elucidation of the crystal size-dependent nature of kinetic and acidity effects. The impact of Brønsted acid sites can be eliminated by neutralization through exchange with Na^+/K^+ ions. The negligible role of Lewis acid sites is confirmed from the study of a large-crystal Sn-MFI zeolite. By utilizing a controlled synthesis approach we are able to better account for the chemical interaction of *o*-Ps with acid centers, providing critical insights for the determination of pore quality in zeolites by PALS.

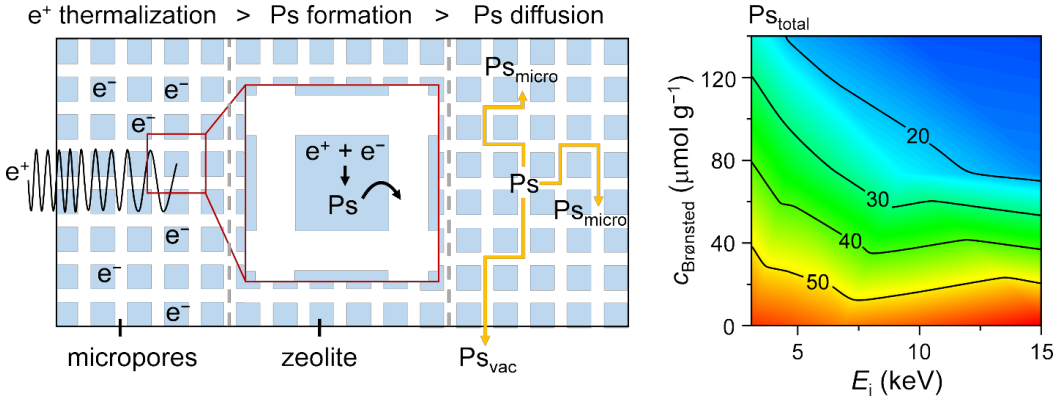

Figure 1 Schematic of the formation, diffusion, and annihilation of *o*-Ps within a zeolite and correlation of Ps_{total} with the concentration of Brønsted acid sites and positron implantation depth.

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[2] a) V. L. Goldanskii, V. G. Firsov, *Annu. Rev. Phys. Chem.* **1971**, 22, 209; b) W. F. Huang, D. C. Huang, P. K. Tseng, *Catal. Lett.* **1994**, 26, 269.